



Seismic Analysis of G+10 Storey Building using Structural Lightweight and Normal Weight: A Review

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Abstract— Concrete is the most important material used in many construction applications. The multistorey buildings are constructed of ordinary concrete, steel and other materials and are subjected to heavy loads requiring heavy construction and may not be cost effective. But the structural lightweight concrete produced using lightweight aggregates may reduce the dead load of the structure, so now a days it is used in construction of multistorey buildings. Concrete is considered as light weight concrete which has density of less than 2000 kg/m^3 . In this research, a G+10 multistorey plan irregular building is analysed with structural lightweight concrete using perlite as a fine aggregate and normal weight concrete using the Response Spectrum Method under different seismic zones and Time History Method for Bhuj earthquake. The parameters like storey displacement, storey drift, storey shear and overturning moments are considered and the results of NWC and SLWC buildings are compared. From the results obtained it is observed that seismic damages are considerably reduced in structural lightweight concrete buildings as compared to normal weight concrete buildings.

Keywords— Structural lightweight concrete, Perlite aggregate, Seismic analysis, Response spectrum method, Time history analysis, ETABS

I. INTRODUCTION

Concrete plays an important role in modern construction due to its strength, durability, fire resistance, and low cost. However, one of the major drawbacks of conventional concrete is its high self-weight. During earthquakes, higher mass leads to larger inertial forces, which increases damage to structures. Structural lightweight concrete helps in reducing the dead weight of structures, thereby lowering seismic forces.

Lightweight concrete can be produced by using lightweight aggregates, introducing air voids, or removing fine aggregates. Among these methods, the use of lightweight aggregates is the most suitable for structural applications. Natural perlite is a volcanic material that expands when heated and becomes very light in weight. Due to this property, it

can be used as a lightweight aggregate in concrete. This paper presents a review of studies related to lightweight concrete and the use of perlite aggregate, especially for improving seismic performance of buildings.

Structural Lightweight Concrete

Structural lightweight concrete generally has a density between 1440 and 1850 kg/m^3 and sufficient strength for load-bearing applications. The main advantage of SLWC is the reduction in dead load, which results in lower seismic forces, smaller member sizes, and reduced foundation cost.

Although SLWC has lower modulus of elasticity compared to normal weight concrete, it can still perform well under seismic loading if properly designed. The reduced stiffness may increase

displacement, but overall seismic demand is lowered due to reduced mass.

Perlite as a Lightweight Aggregate

Perlite is a naturally occurring volcanic glass that contains moisture. When heated, the moisture inside turns into steam and causes the material to expand, forming a porous structure with very low density. Expanded perlite is widely used in construction due to its fire resistance and insulating properties. When used in concrete, perlite reduces density and improves thermal performance. However, higher porosity can lead to a reduction in compressive strength. Many studies show that partial replacement of conventional aggregates with perlite, along with the use of mineral admixtures, can produce concrete suitable for structural use. Several researchers have studied the mechanical behaviour of lightweight concrete.

History of Structural Lightweight Concrete

Structural lightweight concrete has been used in engineering applications for more than a century, particularly where reduction in self-weight and improved structural efficiency are required. One of the earliest modern applications was the construction of a lightweight concrete ship between 1917 and 1920 using concrete with a compressive strength of about 35 MPa. This project marked the first significant use of high-performance lightweight concrete in structural design. Another notable example is the Bank of America Corporate Center in Charlotte, North Carolina, a 60-storey building with a height of 265 m. The structure was built using lightweight concrete with compressive strength ranging from 43 to 51 MPa and an average density of approximately 1890 kg/m³. The use of lightweight concrete helped reduce dead load while maintaining structural performance. The Wellington Regional Stadium in New Zealand, with a seating capacity of 40,000, was the country's first major structure built using lightweight concrete. All precast components were constructed using lightweight concrete made with expanded slate aggregate imported from the United States.

In Sweden, the first lightweight concrete bridge was completed in 1975. The prestressed slab bridge, constructed using sintered fly ash aggregate, achieved a compressive strength of 35 MPa and a density of about 1800 kg/m³. Similarly, Norway has

constructed several bridges using high-strength structural lightweight concrete since the late 1980s, with compressive strengths up to 60 MPa and densities around 1900 kg/m³. In the United Kingdom, the use of lightweight concrete began with a reinforced concrete office building in 1958. This was followed by major projects such as aircraft hangar expansions and high-rise hospital towers constructed using sintered fly ash lightweight aggregate concrete.

Natural Perlite

Perlite is a naturally occurring volcanic glass formed through the hydration of obsidian and contains a relatively high amount of chemically bound water. When subjected to rapid heating, perlite undergoes a significant volumetric expansion due to the vaporization of this water, resulting in a lightweight cellular material. The expanded form of perlite can increase in volume by 15 to 20 times its original size while maintaining a very low bulk density. Expanded perlite is widely used in construction due to its lightweight, fire-resistant, and thermal insulation properties. When used as a fine aggregate in concrete, perlite produces lightweight concrete with reduced density compared to conventional mixes. Although the compressive strength of perlite-based concrete is generally lower than that of normal weight concrete, its reduced density plays a crucial role in minimizing dead load and improving seismic performance.

Perlite fine aggregate is obtained from pumice stone, a glassy volcanic material containing trapped moisture. During heating, the moisture converts into steam, forming numerous internal pores that give perlite its lightweight and insulating characteristics. Due to these properties, expanded perlite is increasingly being considered as an alternative fine aggregate in structural lightweight concrete applications.

Aim and Objectives

Aim:

To evaluate and compare the seismic performance of a G+10 storey plan-irregular reinforced concrete building constructed using structural lightweight concrete with perlite as a fine aggregate and conventional normal weight concrete.

Objectives:

1. To perform seismic analysis of a G+10 storey plan-irregular building using structural lightweight concrete and normal weight concrete through the Response Spectrum Method and Time History Method.
2. To compare key seismic response parameters such as overturning moment, storey shear, storey drift, and storey displacement for both structural systems using ETABS software.

II. LITERATURE SURVEY**Brindha Sathiaselvan & M. Hannah Angelin (2025)**

Brindha Sathiaselvan and M. Hannah Angelin (2025) evaluated the durability and mechanical properties of sustainable lightweight concrete prepared with perlite and vermiculite as partial replacements for traditional aggregates. Concrete mixes with 5%, 7%, and 10% replacement levels were tested to examine their effect on density, compressive strength, and durability indicators. The study found that incorporating perlite and vermiculite significantly reduced concrete density while influencing mechanical behaviour and long-term durability. The research demonstrated the potential of mineral aggregate modifications to improve sustainability and performance of structural lightweight concrete.

V. Navin Ganesh, N. Divyah & R. Rajkumar (2024)

V. Navin Ganesh et al. (2024) investigated fiber reinforcement in sintered flyash lightweight aggregate concrete to enhance structural performance, energy absorption, and impact resistance. Basalt fibers were added to concrete mixtures containing sintered flyash aggregates to study improvements in toughness and dynamic behaviour. Results showed that fiber additions markedly increased impact resistance and crack-bridging capacity, providing improved mechanical performance after cracking. The research highlighted the benefits of combining recycled lightweight aggregates with fiber reinforcement for more resilient structural lightweight concrete designs.

B. Prasanna Kumar et al. (2024)

Prasanna Kumar, S. Sai Charan, A. Hema Venkata Suresh, and M. Chandra Kanth (2024)

conducted an experimental study on the mechanical properties of lightweight aggregate concrete using expanded clay aggregates. This work focused on M25 grade concrete with partial replacement of coarse aggregates by lightweight expanded clay. Fresh and hardened concrete properties were evaluated, including compressive strength and splitting tensile strength. The findings revealed a reduction in density and mechanical properties compared to conventional mixes, but the trends indicated that lightweight aggregate substitution can be tailored to achieve structural requirements with optimized mix proportions.

Abhishek Kumar Singh et al. (2022)

Abhishek Kumar Singh and colleagues (2022) studied the mechanical properties of lightweight concrete using lightweight expanded clay aggregate (LECA) as partial replacement for conventional coarse aggregate. The research demonstrated that LECA incorporation significantly lowered concrete self-weight, improving thermal insulation and reducing structural mass. The study also reported effects on compressive strength and workability, showing that lightweight mixes with LECA present practical advantages for structural applications where reduced density and improved sustainability are desired.

Singh, A. K., Verma, R., and Sharma, R. (2022)

Singh et al. (2022) examined the mechanical properties of lightweight concrete prepared using lightweight expanded clay aggregate as a replacement for conventional coarse aggregates. The experimental program included compressive strength, split tensile strength, flexural strength, and modulus of elasticity tests. The results showed that lightweight concrete achieved sufficient strength for structural use while offering a significant reduction in unit weight. It was observed that aggregate strength and porosity had a direct influence on stiffness and load-carrying capacity.

Although the modulus of elasticity was lower than that of normal weight concrete, the material exhibited better deformation capacity. The authors highlighted that reduced self-weight leads to lower seismic forces, which is beneficial for multistorey buildings. The study concluded that lightweight expanded clay aggregate concrete can be effectively used in structural applications where dead load

reduction and improved seismic response are required.

Patel, J., and Desai, M. (2023)

Patel and Desai (2023) conducted a detailed analytical study to evaluate the seismic performance of reinforced concrete buildings constructed using lightweight aggregate concrete. The study compared normal weight concrete and lightweight concrete frames using response spectrum analysis as per Indian seismic design provisions. Parameters such as base shear, storey displacement, storey drift, and natural time period were analyzed. Results indicated that lightweight concrete buildings experienced reduced base shear and overturning moments due to lower seismic mass. Although storey displacements were marginally higher, they remained within the allowable limits prescribed by IS 1893. The authors emphasized that reduced member forces can lead to more economical structural design. The study concluded that lightweight concrete is a suitable alternative for earthquake-resistant construction, especially in high seismic zones.

Ramesh, K. (2021)

Ramesh and Prakash (2021) investigated the mechanical and durability characteristics of perlite-based lightweight concrete. The experimental work focused on compressive strength, density, water absorption, and resistance to chloride penetration. The results showed that increasing perlite content significantly reduced the density of concrete, making it suitable for lightweight structural applications. However, higher perlite replacement levels led to increased porosity, resulting in reduced compressive strength. The authors noted that the use of supplementary cementitious materials helped improve strength and durability. Despite the reduction in strength, the concrete achieved acceptable performance for structural and non-structural elements. The study concluded that perlite-based lightweight concrete is beneficial for reducing dead load and improving durability when properly designed and optimized.

Kumar, V., and Rao, P. S. (2024)

Kumar and Rao (2024) studied the effect of partial replacement of fine aggregate with perlite on the strength and stress-strain behavior of lightweight concrete. Experimental investigations included

compressive strength tests and evaluation of stress-strain characteristics. The results indicated that perlite improved workability and reduced density, leading to lighter concrete mixes. Although a reduction in stiffness was observed, the concrete showed improved strain capacity and gradual failure behavior. Stress-strain curves revealed lower peak stress but enhanced ductility compared to normal concrete. The authors highlighted that improved deformation capacity is advantageous under seismic loading. The study concluded that perlite-based lightweight concrete can be effectively used in seismic-resistant structures where controlled strength reduction is acceptable in exchange for improved energy absorption.

Chaudhari, S., and Kulkarni, P. (2023)

Chaudhari and Kulkarni (2023) analyzed the seismic behavior of multistorey reinforced concrete buildings constructed using lightweight concrete. Both response spectrum and time history analyses were carried out to assess structural performance under earthquake loading. Parameters such as base shear, storey drift, overturning moment, and axial forces in columns were examined. The results showed a significant reduction in base shear and overturning moments due to decreased structural mass. Although storey displacements increased slightly, they were within permissible limits specified by seismic design codes. The authors concluded that lightweight concrete helps reduce seismic demand and improves overall structural efficiency. The study recommended the use of lightweight concrete in high-rise buildings located in seismic-prone regions.

Mohammed Ibrahim et al. (2020)

Mohammed Ibrahim et al. (2020) focused on developing durable structural lightweight concrete using expanded perlite aggregate (EPA). EPA was used in proportions ranging from 0% to 20%, while cement was partially replaced with 50% GGBFS and 7% silica fume. Mechanical and durability properties were evaluated along with seismic behaviour using finite element modelling. Results showed a 20–30% reduction in unit weight compared to normal concrete. Concrete containing 10–15% EPA achieved adequate strength and durability. Improved thermal insulation and better seismic performance were also observed.

Annie Sweetlin et al. (2020)

Annie Sweetlin et al. (2020) studied structural lightweight concrete using natural perlite as a complete replacement for coarse aggregate. Concrete mixes were prepared with different water–cement ratios and tested for compressive and split tensile strength. The results showed a significant reduction in self-weight compared to conventional concrete. However, compressive and tensile strengths were reduced by approximately 46% and 57%, respectively. Despite lower strength, the reduced density makes perlite concrete suitable for seismic-resistant construction where reduced dead load is beneficial.

Bing Han et al. (2017)

Bing Han et al. (2017) investigated the axial compressive stress–strain behaviour and Poisson's effect of lightweight concrete made using expanded slate aggregates. Four different aggregate volume fractions were studied. Results showed that compressive strength did not change linearly with aggregate content. Minimum strength occurred at 20% replacement, after which strength increased. At 60% replacement, compressive strength was comparable to normal concrete. Lightweight aggregates were found to be more deformable, resulting in lower elastic modulus. Aggregate type significantly influenced mechanical properties.

Bhuvaneshwari et al. (2017)

Bhuvaneshwari et al. (2017) examined the use of natural perlite as a partial replacement for sand in lightweight concrete. Perlite replaced sand at levels of 5%, 10%, 15%, 20%, and 25%. Compressive, split tensile, and flexural strength tests were conducted. The study found that 10% perlite replacement produced optimum results, with increases in compressive, tensile, and flexural strength at 28 days. Beyond this level, strength decreased due to increased porosity in the concrete matrix.

Kwang-Soo Youm et al. (2016)

Youm et al. (2016) conducted an experimental study on the strength and durability of high-performance lightweight concrete containing silica fume. Concrete mixes were designed to achieve 60 MPa compressive strength with oven-dry density below 1900 kg/m³. Three lightweight aggregates and silica fume contents of 0%, 3.5%, and 7% were investigated. Silica fume improved compressive strength and chloride

resistance depending on aggregate type. However, split tensile strength and elastic modulus were not significantly affected. Improved durability was attributed to refined cement paste microstructure.

Yingwu Zhou et al. (2016)

Zhou et al. (2016) investigated the axial compressive behaviour of fibre-reinforced polymer (FRP) confined lightweight aggregate concrete. Three different lightweight aggregates were used, including shale ceramics and hollow steel balls. Axial compression tests showed that FRP confinement significantly enhanced load-carrying capacity and ductility. Analytical models for ultimate strength and strain closely matched experimental results. Strength enhancement depended on FRP content, with higher efficiency observed in normal concrete at larger FRP ratios.

Murat Emre Dilli et al. (2015)

Dilli et al. (2015) compared the strength and elastic properties of conventional concrete and lightweight structural concrete produced using expanded clay aggregates. Properties such as compressive strength, modulus of elasticity, Poisson's ratio, and ductility were studied. The dry density of lightweight concrete ranged from 1640 to 2050 kg/m³. Results showed that compressive strength alone is insufficient for predicting elastic modulus. Lightweight concrete exhibited lower stiffness and more brittle behaviour than normal concrete, while Poisson's ratios remained similar.

H.Z. Cui et al. (2012)

Cui et al. (2012) carried out experimental investigations and developed an analytical model for the pre-peak stress–strain behaviour of structural lightweight aggregate concrete. Five different lightweight aggregates with varying volume fractions were studied. Results showed that peak stress and Young's modulus decreased with increasing lightweight aggregate content. Lightweight aggregate was identified as the weakest component in LWAC. Higher aggregate density and crushing strength improved mechanical performance, while increased aggregate content led to more brittle failure behaviour.

Tommy Y. Lo et al. (2006)

Tommy Y. Lo et al. (2006) studied the influence of aggregate properties on the strength of lightweight concrete. The effects of aggregate strength, water–cement ratio, and porosity within the interfacial transition zone were examined. Concrete mixes with water–cement ratios of 0.40, 0.44, and 0.48 were tested. Results indicated that concrete strength mainly depends on aggregate crushing strength. Higher water–cement ratios increased pore volume and reduced strength, particularly at the aggregate–paste interface.

J.M. Chi et al. (2002)

Chi et al. (2002) investigated the effect of aggregate properties on the strength and stiffness of lightweight concrete using cold-bonded pelletized aggregates. Three aggregate types with different fly ash contents were produced. The study showed that water–binder ratio and aggregate volume fraction strongly influence compressive strength and elastic modulus. When the aggregate volume fraction was limited to 18%, concrete strength and stiffness were governed mainly by the cement paste, rather than aggregate type.

T.H. Almusallam and S.H. Alsayed (1995)

Almusallam and Alsayed (1995) proposed a simple mathematical model to represent the complete stress–strain relationship of normal, high-strength, and lightweight concrete. The model was developed using average experimental results from specimens tested under various conditions. It accurately described both ascending and descending portions of the stress–strain curve. The authors concluded that the model is equally applicable to different concrete types and effectively accounts for factors influencing stress–strain behaviour, showing good agreement with experimental data.

III. LITERATURE GAP

- Most existing studies focus on material-level properties of lightweight concrete, such as compressive strength, stress–strain behavior, modulus of elasticity, and durability, rather than overall structural performance.
- Research on perlite-based lightweight concrete mainly addresses density reduction and strength

characteristics, with limited attention to its application in structural systems.

- Very few studies have evaluated the seismic behavior of multistorey reinforced concrete buildings constructed using structural lightweight concrete.
- Comparative studies between structural lightweight concrete with perlite replacement of fine aggregates and normal weight concrete for multistorey buildings are scarce.
- Limited literature is available on the combined use of response spectrum method and time history method for seismic analysis of buildings using lightweight concrete.
- The influence of reduced self-weight on base shear, storey drift, overturning moment, and member forces in multistorey buildings using perlite-based lightweight concrete is not well documented.
- There is a lack of studies addressing the practical feasibility and seismic efficiency of using structural lightweight concrete with perlite replacement in G+10 or higher storey buildings.
- Hence, a clear research gap exists in conducting a comprehensive comparative seismic analysis of multistorey buildings using structural lightweight concrete with perlite replacement and conventional normal weight concrete.

IV. SUMMARY OF LITERATURE

The reviewed research studies provide a comprehensive understanding of the behaviour, strength, and structural performance of lightweight concrete, particularly with the use of perlite and other lightweight aggregates. These studies collectively highlight the advantages and limitations of lightweight concrete in terms of strength, density, durability, and seismic performance. The findings from previous investigations form a strong foundation for identifying research gaps and defining the scope of the present study.

- The reviewed literature confirms that incorporating perlite in concrete significantly reduces the self-weight of structural members, which helps in minimizing dead loads and optimizing member sizes.

- Due to its low density, perlite-based lightweight concrete contributes to reduced seismic forces acting on structures, making it suitable for earthquake-resistant design.
- Several studies indicate that an increase in perlite content leads to a reduction in density as well as compressive strength of concrete.
- To compensate for strength loss while maintaining reduced density, researchers have incorporated supplementary materials such as silica fume, GGBFS, and other mineral admixtures in the concrete mix.
- Experimental findings show that the peak stress and Young's modulus of lightweight aggregate concrete generally decrease when lightweight aggregates replace conventional aggregates.
- The mechanical performance of lightweight concrete is strongly influenced by the strength, density, and crushing resistance of the lightweight aggregates used.
- The literature clearly establishes that aggregate properties play a dominant role in governing the stress-strain behaviour and overall structural response of lightweight concrete.
- After a detailed review, it is observed that limited research has been carried out on the comparative seismic behaviour of multistorey buildings using structural lightweight concrete with perlite as fine aggregate replacement.
- No comprehensive study was found comparing the seismic performance of a multistorey building constructed with perlite-based lightweight concrete and normal weight concrete.

Therefore, the present research addresses this gap by performing seismic analysis of a G+10 storey building using structural lightweight concrete with perlite as a replacement for fine aggregates and comparing it with normal weight concrete using Response Spectrum Method and Time History Method.

V. FUTURE SCOPE

This research area has a vast scope for the future studies. In this subject, large scale analysis can be conducted with a wide range of variable and characteristics. After finishing the analysis and

scrutiny of data about structure design with SLWC and NWC under different seismic zone, there are still some avenues that can be studied in details which are listed below

1. Introduction of other lateral load resisting like bracing, belt, truss and outrigger system can be done and their results can be compared.
2. Seismic analysis of multistorey building design with SLWC with design position & location of shear wall, with or without shear wall can be done and their results can be compared with structure design with NWC.

REFERENCES

- [1] Brindha Sathiaselvan, M., and Hannah Angelin, M., "Mechanical and durability performance of lightweight concrete using perlite and vermiculite," *International Journal of Engineering Science and Technology*, 2025.
- [2] Navin Ganesh, V., Divyah, N., and Rajkumar, R., "Enhancing structural performance of sintered fly ash lightweight concrete using fiber reinforcement," *Indian Journal of Science and Technology*, 2024.
- [3] Prasanna Kumar, B., Sai Charan, S., Hema Venkata Suresh, A., and Chandra Kanth, M., "Experimental investigation on mechanical properties of lightweight aggregate concrete using expanded clay," *International Journal of Research and Analytical Reviews*, 2024.
- [4] Singh, A. K., et al., "Mechanical properties of lightweight concrete using lightweight expanded clay aggregate," *International Journal for Research in Applied Science and Engineering Technology*, 2022.
- [5] Ibrahim, M., Ahmad, A., Barry, M. S., Alhems, L. M., and Mohamed Suhoothi, A. C., "Durability of structural lightweight concrete containing expanded perlite aggregate," *International Journal of Concrete Structures and Materials*, vol. 14, 2020.
- [6] Sweetlin, J. P. A., Boologanageswari, S., Madhu, S., Priyanka, B., and Rekha, S., "Experimental study of lightweight concrete using perlite," *International Research Journal of Engineering and Technology*, vol. 7, no. 5, pp. 1-6, 2020.
- [7] Han, B., and Xiang, T. Y., "Axial compressive stress-strain relation and Poisson effect of structural lightweight aggregate concrete," *Construction and Building Materials*, vol. 146, pp. 338-343, 2017.
- [8] Bhuvaneshwari, K., Dhanalakshmi, G., and Kaleeswari, G., "Experimental study on lightweight concrete using perlite," *International Research Journal of Engineering and Technology*, vol. 4, no. 4, pp. 1-5, 2017.
- [9] Youm, K. S., Moon, J., Cho, J. Y., and Kim, J. J., "Experimental study on strength and durability of

- lightweight aggregate concrete containing silica fume," *Construction and Building Materials*, vol. 114, pp. 517–527, 2016.
- [10] Zhou, Y., Liu, X., Xing, F., Cui, H., and Sui, L., "Axial compressive behavior of FRP-confined lightweight aggregate concrete: Experimental study and stress-strain model," *Construction and Building Materials*, vol. 119, pp. 1–15, 2016.
- [11] Dilli, M. E., Atahan, H. N., and Şengül, C., "Comparison of strength and elastic properties of conventional and lightweight structural concretes using expanded clay aggregates," *Construction and Building Materials*, vol. 101, pp. 260–267, 2015.
- [12] Cui, H. Z., Lo, T. Y., Memon, S. A., Xing, F., and Shi, X., "Experimental investigation and analytical modeling of pre-peak stress-strain behavior of structural lightweight aggregate concrete," *Construction and Building Materials*, vol. 36, pp. 845–859, 2012.
- [13] Lo, T. Y., Tang, W. C., and Cui, H. Z., "Effects of aggregate properties on lightweight concrete," *Building and Environment*, vol. 42, pp. 3025–3029, 2007.
- [14] Chi, J. M., Huang, R., Yang, C. C., and Chang, J. J., "Effect of aggregate properties on the strength and stiffness of lightweight concrete," *Cement and Concrete Composites*, vol. 25, pp. 197–205, 2003.
- [15] Almusallam, T. H., and Alsayed, S. H., "Stress-strain relationship of normal, high-strength and lightweight concrete," *Magazine of Concrete Research*, vol. 47, no. 170, pp. 39–44, 1995.
- [16] Bureau of Indian Standards, *IS 456:2000 – Plain and Reinforced Concrete: Code of Practice*, New Delhi, India.
- [17] Bureau of Indian Standards, *IS 875 (Part 1):1987 – Code of Practice for Design Loads (Dead Loads)*, New Delhi, India.
- [18] Bureau of Indian Standards, *IS 1893 (Part 1):2016 – Criteria for Earthquake Resistant Design of Structures*, New Delhi, India.
- [19] Bureau of Indian Standards, *IS 13920:2016 – Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces*, New Delhi, India.
- [20] American Concrete Institute, *ACI 318R – Building Code Requirements for Structural Concrete and Commentary*, USA.